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MEASUREMENTS OF  
RADIOFREQUENCY (RF) BODY  
POTENTIAL AND BODY CURRENT IN  
PERSONNEL ABOARD TWO CLASSES  
OF NAVY SHIPS

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## ABSTRACT

Recently revised radiofrequency (RF) exposure standards contain limits on the RF current induced in the bodies of irradiated personnel. Both current-to-ground and hand-contact current are limited, but heretofore no systematic shipboard measurement of these currents has been conducted. To provide the needed information, we measured irradiation-induced RF body currents in personnel aboard LDH-1 and PHM-1 classes of Navy ships. Both current-to-ground and hand-contact current were measured using specialized, prototype instruments. The Naval Sea Systems Command (NAVSEA) "Burngun" was also used to assess the indicated RF voltage on various metallic topside objects. Results showed that shipboard body currents are not small and can often exceed the draft Department of Defense Instruction (DODI) 6055.11 limit of 100 mA per limb for the "high-frequency" (HF) spectrum. We found that increased spacing between the feet and the deck decreased the RF current-to-ground in personnel. We also used a metallic, conductive glove to demonstrate the concept that RF burns to the hand can be prevented with the use of "conductive" gloves. Normally, "insulating" gloves have been used for this purpose, but such gloves are bulky and subject to aging and dielectric breakdown (flashover). Conductive gloves, however, can be lightweight and are not subject to flashover because the RF current is capacitively coupled to the conductive glove over the large surface area of the wrist and hand. We recommend that measures be taken to reduce RF body currents in Navy shipboard personnel who are subject to HF irradiation.

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## INTRODUCTION

After the promulgation of ANSI C95.1-1982 (1), Gandhi, Chatterjee, Wu, and Gu (4) predicted that energy deposition in the human leg could exceed the criterion specific absorption rate (SAR) at ANSI recommended safety levels. Gandhi, Chen, and Riazi (5) later measured large body currents in individuals exposed to far-field irradiation regions and to irradiation from industrial radiofrequency (RF) heat sealers. Chen and Gandhi (2) measured ankle surface temperatures on human subjects and found substantial rates of surface heating from which high internal SARs were projected. Hoque and Gandhi (6) and Dimbylow (3) used theoretical calculations that included bones and other tissue to predict similar results in the ankles. These findings demonstrated that relatively large body and contact currents could exist near Navy irradiation systems in the high-frequency (HF) band (2-30 MHz) and could result in SARs that exceed the safe exposure criterion.

Recently promulgated nonionizing radiation exposure standards (7) contain limits on RF currents in the body. Both body-to-ground and contact currents are limited. The limits, moreover, are frequency dependent such that lower currents are allowed at lower frequencies (3-100 kHz), and a maximum of 100 mA per limb is allowed above 100 kHz. That limit should theoretically prevent RF burns and keep ankle and wrist SARs below 20 W/kg.

Based on previous shipboard RADHAZ-related measurements conducted by NAMRL personnel, we knew that RF-induced body currents exist, particularly near topside HF transmitting antennas. This study was conducted to quantitate typical shipboard body currents. We also measured RF body potential (voltage) for certain configurations and explored ways to reduce RF body currents and eliminate RF burns.

## METHODS

Two classes of ships were used in these measurements. First was the Navy's new multipurpose amphibious assault platform, USS WASP (LHD-1). We conducted measurements at three locations near the signal light and port flagbag as shown in Fig. 1. Irradiation parameters aboard USS WASP consisted of two 700-W, continuous wave (CW) signals (16 and 18 MHz) that were transmitted from the twin-whip antenna system. We measured power density from which we extracted total electrical field (E-field), vertical E-field component, body-to-ground current, RF contact voltage, and RF hand-contact current.

The second type of ship was a Navy hydrofoil. We conducted measurements at three locations aboard USS PEGASUS (PHM-1) and USS ARIES (PHM-5) as shown in Figs. 2 and 3. Irradiations at 28.6 and 2.343 MHz were used individually at a power output of 0.9 to 1.0 kW. We measured all parameters that were recorded aboard USS WASP with the addition of body-to-ground current's simultaneously recorded during the hand-contact current measurements.

Specialized instrumentation was used to obtain RF body currents. Figure 4 shows two prototype RF current meters (Model GC-2, University of Utah). Normally, the GC-2 is a stand-on device, but Fig. 4 shows how one meter was fitted with a conductive handle and a pointed tip for touching metal objects and recording hand-contact currents. Power density was measured with an isotropic meter and E-field probe (Models 8616/8662, Narda/Loral, Inc.). The vertical E-field component was measured with a single-axis sensor (Model EFS-1, IFI, Inc.). Voltage on the touched objects was measured with a handheld RF voltmeter known as the NAVSEA "burngun" shown in Fig. 5. The "burngun" is a high-impedance voltmeter with conductive handle grips to connect one side of the meter to the body. It has evolved over the years and has been produced by contractors to the Naval Sea Systems Command.

Procedures were simply to have members of the NAMRL measurement team either stand on the RF current meter at the selected site during irradiation or touch the designated object with the tip of the modified RF

current meter or burngun. Each measurement took less than 15 s and did not subject the measured individuals to RF overexposure; RF burns were prevented by because of the large, metallic areas on the instrument handles.

## RESULTS

Table 1 gives the WASP results and shows relatively low body-to-ground currents. Contact currents and burngun voltages, however, were quite high and indicative of RF burn locations. Table 2 gives the PEGASUS and ARIES results and shows relatively high RF currents and voltages at all tested locations. A particularly interesting feature shown in Table 2 is that body-to-ground current tripled with hand-contact current at one location but decreased at the two other locations. This puzzling observation is evidence that irradiated shipboard personnel are, at times, (and unknowingly) closely coupled as parasitic elements of the HF irradiation system.

## DISCUSSION AND CONCLUSION

These results show that shipboard body-to-ground and contact currents are not small, especially in light of the fact that the irradiation system on WASP is capable of much higher power operation in terms of the many additional communication channels available. Some sort of protection and/or mitigation effort is needed. Aboard USS WASP, we conducted a cursory check of body-to-ground current as a function of spacing distance between the foot and the deck. We found that current-to-ground decreased significantly when a 1-inch thick piece of dry dielectric material (celotex) was placed under the RF current meter. This finding was consistent with results previously obtained near shipboard RF heat sealers operating at 27.12 MHz.

Aboard USS ARIES, we conducted a cursory test of a NAMRL-developed concept to prevent RF burns to the hand. A stainless-steel, chain-mail butcher's glove was donned; finger contact was then made at some of the locations listed in Table 2. Even though visible arcing was seen between the glove and the touched metal object, no finger burn occurred. Therefore, shipboard RF burns might be prevented if practical conductive gloves could be produced. The stainless-steel glove that we used was unsuitable for routine shipboard use, but a highly conductive, elastic textile material could, perhaps, be manufactured to serve as the base material of a practical, protective garment.

An additional protective feature of using conductive gloves sufficient to cover the wrist would protect the wearer from critical wrist heating. Under these conditions, the 100 mA-per-limb limit might not apply because high RF current densities in the wrist are avoided. Likewise, conductive socks could be worn to eliminate RF-induced ankle heating, and, as before, the 100-mA limit might not apply.

We conclude that shipboard body currents can be dangerously high for certain topside configurations and irradiation parameters. We, therefore, recommend that measures be taken to reduce these currents and have suggested methods to ameliorate the situation.

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Table 1. Exposure parameters at signaling station, USS WASP (LDH-1)

Location	Total E-field (V/m)	Vertical E-field (V/m)	RF body-to- ground current* (mA $\pm$ SD) (N = 6)	"Buengun" potential (V)	Hand-contact current (mA)
Signal Light	124	112	66 $\pm$ 16	240	557
Port flag bag:					
Right side	124	94	55 $\pm$ 13	270 <sup>†</sup>	385 <sup>†</sup>
Left side	124	68	66 $\pm$ 17	225 <sup>†</sup>	276 <sup>†</sup>
Halyard station	105	17	15 $\pm$ 6	20	157

\*Body-to-ground current was measured without hand-contact

<sup>†</sup>Average of upper and lower flag rack measurements

Table 2. Exposure parameters aboard PHM-3 class ships

Location and frequency	Total E-field (V/m)	Vertical E-field (V/m)	RF body-to- ground current (mA $\pm$ SD) (N = 3)		"Burngun" potential* (V)	Hand- contact current (mA)
			Touch	No touch		
Near whip antenna 28.600 MHz	70	41	298 $\pm$ 14	91 $\pm$ 13	440	562
Near main mast 28.600 MHz	28	19	100 $\pm$ 22	146 $\pm$ 46	353	397
Aft eyebolt 2.343 MHz	496	300	42 $\pm$ 23	105 $\pm$ 34	130	166

\* Average of two measurements

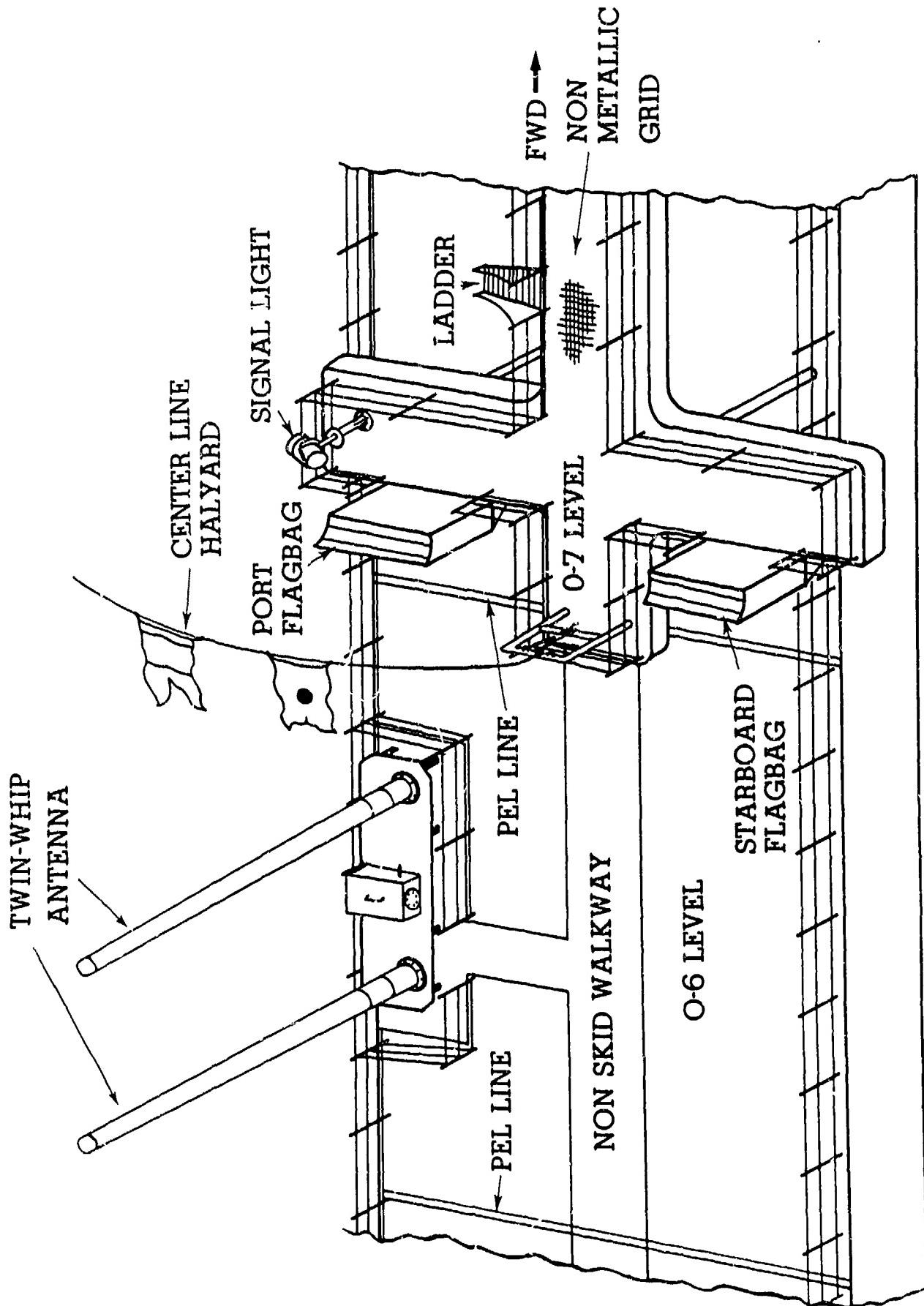


Figure 1. Pictorial view of LHD-1 class ship with the twin-whip antenna configuration.

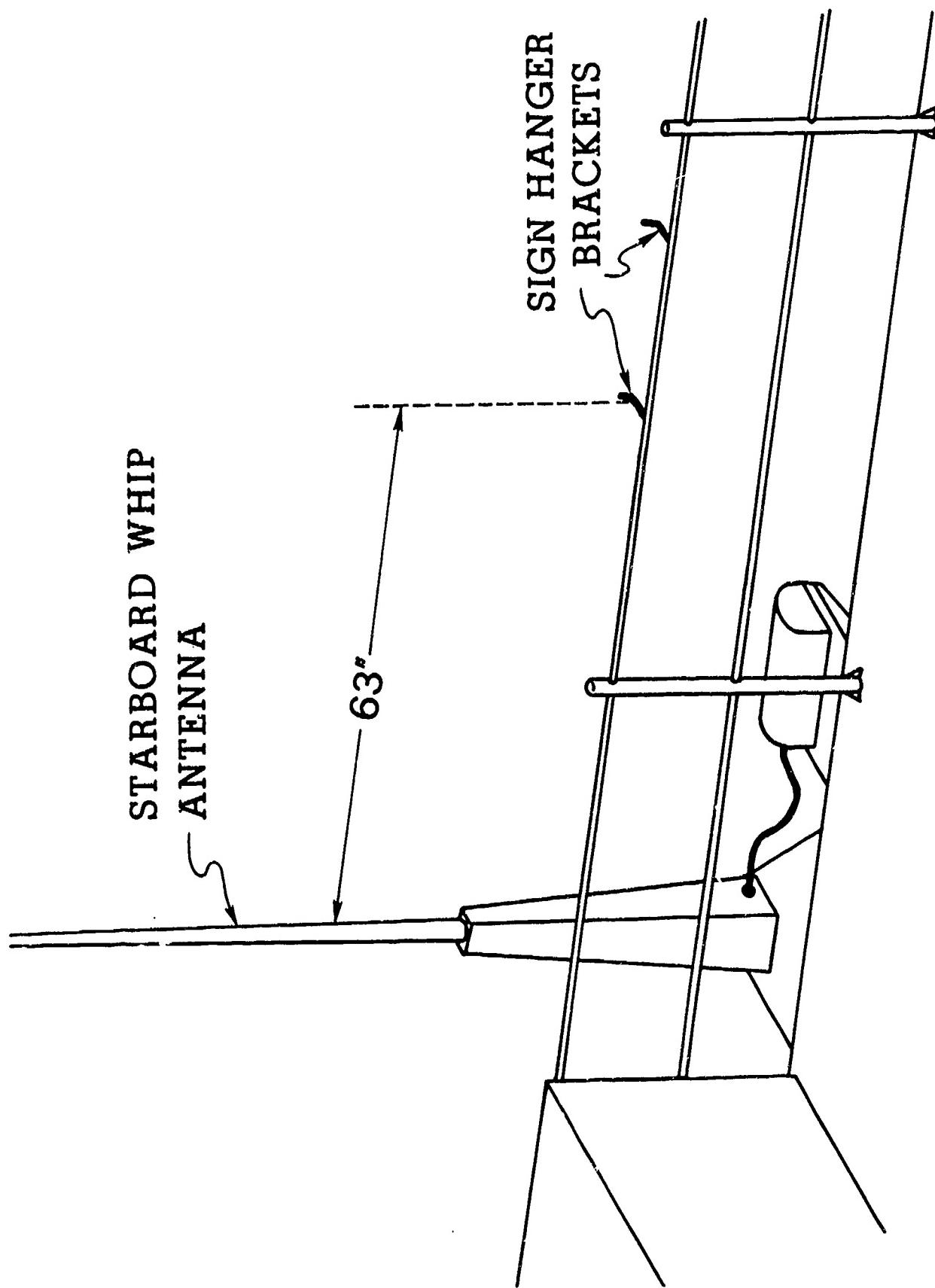


Figure 2. Pictorial view of PHM-1 class ship with the whip antenna configuration.

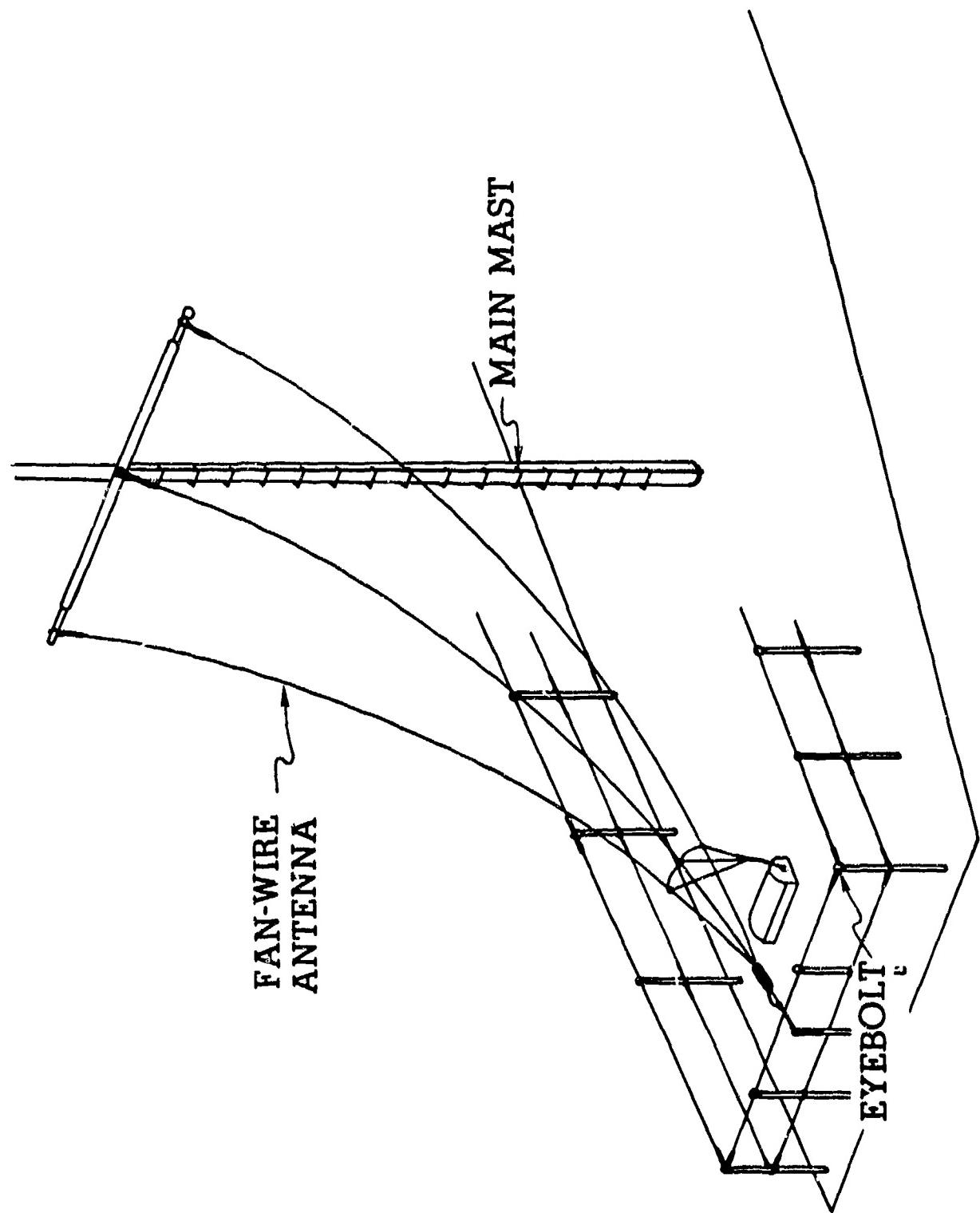


Figure 3. Pictorial view of PHM-1 class ship with the fan-wire antenna configuration.

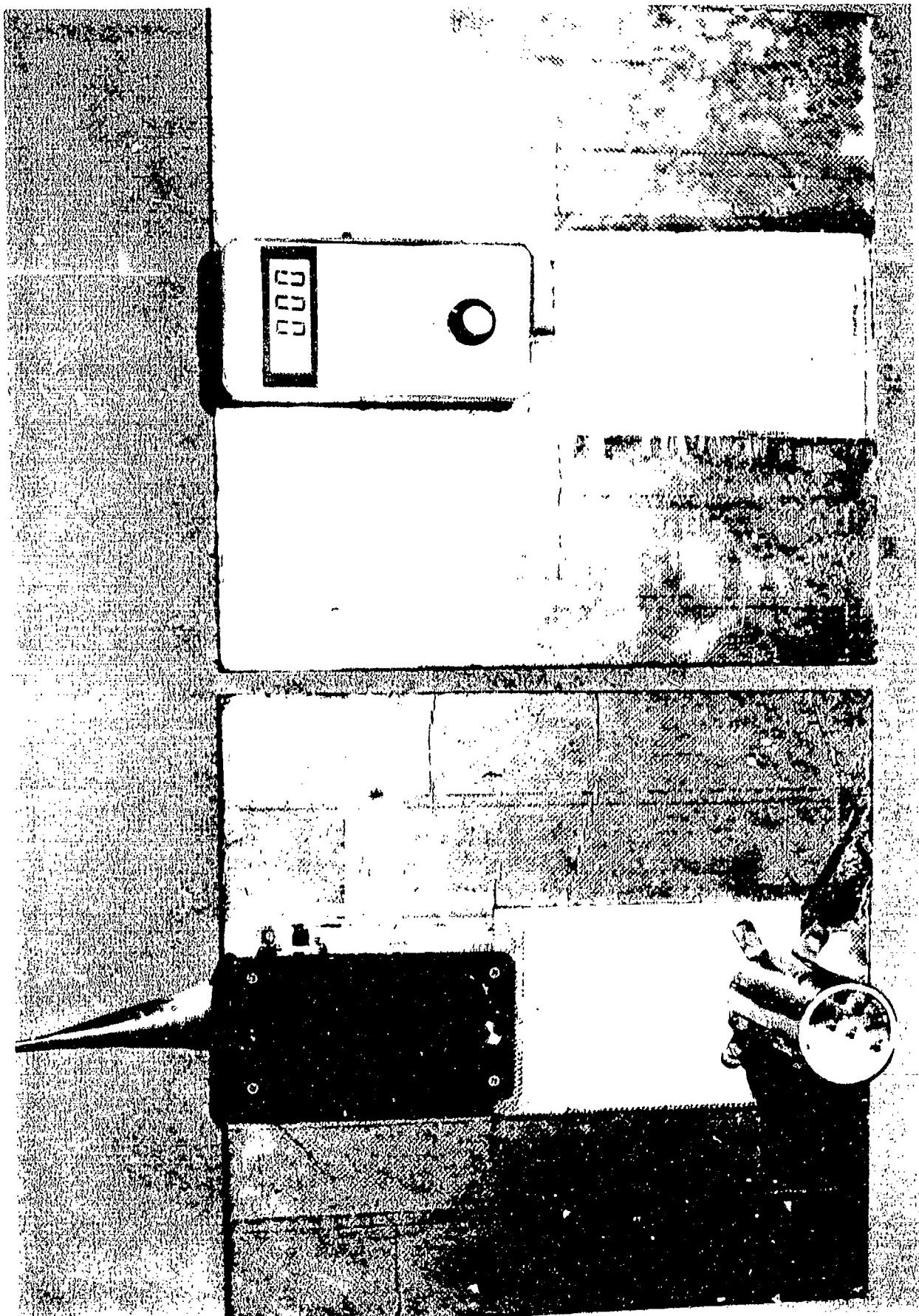


Figure 4 View of prototype RF current meters, modified GC-2 (left) and GC-2 (right).



Figure 5. View of the NAVSEA "burngun."

# REPORT DOCUMENTATION PAGE

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